PRINCIPAL ASPECTS REGARDING THE MEASUREMENT OF GROUND ELECTRICAL FIELD FOR OVERHEAD LINES

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In this paper, departing from the main principle and the methods used for the measurement of ground electrical field is presented a method that wants to show this degree of the measurements credibility. The actual methods used for measurements of ground electrical field are based on the electric induction principle, one of these classical method using for the measurement of the electrical field a spherical dipole situated at 1.8 meters above ground at the place where the measurements had to be taken.

Keywords: ground electrical field, electromagnetic compatibility, environment

1. Introduction

The relation overhead line – environment, view from the point of electromagnetic compatibility (EEMC), supposed ground electrical field measurements in transversal profile towards the axis of the line. The way that the measurement operation is developed, the systems and the results, taking into account the measurement and equipment errors, are important elements regarding the credibility degree between the reality and the results.

The method used to establish the level of the errors that appears in a measurement process can give only theoretical determinations and these results must be compared with results obtained from similar situations, and in this way can be certified the validity of the analyse. Such similar situations could have a theoretical or an experimental aspect resulted from measurements or can appear as a combination of these aspects. In this paper a theoretical method used for the measurement of the ground electrical field for an overhead line in a specified case is presented.

2. General issues regarding EEMC and measuring operation

An electromagnetic phenomenon able to influence temporarily or permanently living in the environment is participating in establishing the level of perturbation in a statistical way.

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By measuring in specific conditions it may be determine the limit value of electromagnetic perturbation that can appear without produce dangerous influences on human body. Also it can be measured under experimental conditions susceptibility to electromagnetic disturbances emission, from a minimum statistical value to maximum value as defining elements of immunity and susceptibility, level equal to or greater than the level of immunity set by experiment.

Starting from the values that define an acceptable level of immunity and are not generate safety hazards and electromagnetic compatibility in terms of EEMC can be set the limits of electromagnetic disturbance upon the environment. Can be established by measuring the emission level in the environment and also a limit of emission level compatibility in terms of EEMC.

In this discussion has been emphasized the importance of measurement operation without being marginalized theoretical determination where this is possible.

The objective of this paper, electrical overhead line-environment relationship, viewed in terms of electromagnetic compatibility (EEMC) requires obviously measurements of electrical field across the ground in a transversal profile to the line axis, particularly.

The development mode of the measurement operation, the systems used and the results in terms of errors and appropriate and compatible equipment used for the measurement operation in the specific environment, are important elements constituting the extent of the relationship between desired reality defined by measurement and the results of this activity.

Starting from statistical values of electromagnetic disturbances that do not generate compatibility problems and security threats in terms of EEMC can be determine the allowable limits of electromagnetic disturbances in the environment.

3. The general principle of measuring the electrical field

In establishing a method for measuring the ground electric field it goes from general considerations regarding the measuring of the field. Basically these content items are:

- Electrical potential of an object (in our case the sensor and transducer of the electric field) is considered determined as values by the group of border values in relation to ground potential considered equal with zero;

- The presence of measuring element, the transducer, disturbs more or less the configuration of the electrical field, but this configuration is determined. Hence, as a consequence, the intensity of the electric field at a point on the surface S of the measured object can be determined from intensity of the surface electric charge, σ, that is given by the classical relationship $\sigma = \varepsilon_0 E$. In an alternative electrical field, the current density inside the measured object, the transducer, is given by well known relationship $J = j\omega\sigma$, and finally $J = j\omega\varepsilon_0 E$. The electric current induced in the measured configuration is obtained using the following relation:

$$i_0 = j\omega\varepsilon_0 \int_S E(S)ds \qquad (1)$$

If the transducer is a metallic sphere sectioned into 2 hemispheres, isolated between them, and is located above a plane, than the induced current that can appear between the 2 hemispheres in these specific measurement conditions is $i_0 = 3\pi r^2 \omega\varepsilon_0 E_0$, where E_0 is the intensity of uniform electrical field, unperturbed by the presence of the transducer.

4. Ground electrical field specific problems

One of the most important problems is the elliptic variation of the electric field intensity in time and space. 2 aspects support this fact:

- One can speak about time variation of the ground electric field vector, as amplitude as well as momentary polarization, means that the vector has an important time oscillation at nominal frequency f=50 Hz;
- Starting from a vertical polarization state of the ground electric field vector and its intensity value, at that time, it can be build a complete analytical description, in phasorial and vectorial space, being created in this way a comprehensive analytic model that has a common reference element.

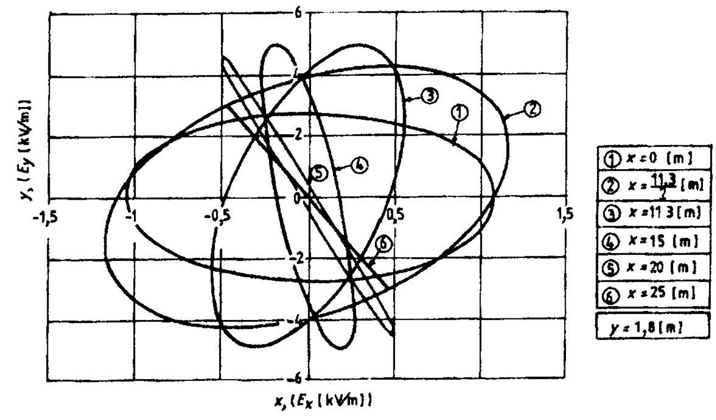

Fig. 1. Elliptic variations of soil electrical field

For a point M (x, y = 1.8 m, x-axis distance towards the overhead line, in a plan perpendicular on it situated in the middle of the opening, characterized by maximum values) in a system of coordinates [x, E (x)] the elliptic variation of ground electric field intensity is represented in Figure 1.

Time variation, putting in evidence this type of distortion, in a spatial representation of coordinates $\lfloor E_x(x)\ E_y(y),\ \omega t \rfloor$, is presented in Figure 2. For the measurements has been used a poles type PAS – 400 – 103. At the middle of the opening coordinates are x = 0, y = 1.8 m under line axis (see ellipse).

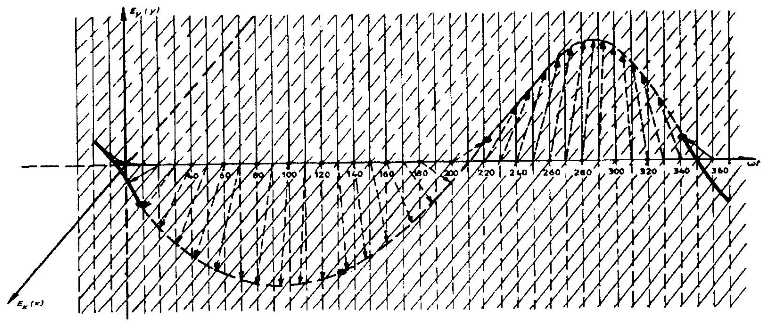

Fig. 2. Electrical field intensity time variation

This representation mode offers a better view regarding the dynamic nature of the ground electrical field vector in terms of direction and amplitude, both depending on voltage fluctuation applied to the 3 phase system of the overhead line.

5. The electrical current induced by electrical uniform field and grounded electrical field

The generally measuring method used in present to calculate the electrical field intensity use for measurements a dipole put in vertical position in the electrical field.

The electrical current induced will determine a sufficient outage as value on impedance adequately chosen and linked between the two hemispheres so as to be measured by a suitable electronic system [3], [5]. The calibration of the measuring can be done under optimal accuracy conditions without a vertical structure of uniform electrical field. Its intensity is a harmonic measure and has the pulsation ϖ (frequency of 50 Hz).

The current value induced into the spherical dipole under calibration conditions is calculated as following [3]:

$$i_{d,e}(t) = 3\pi\varepsilon_0\varpi R^2 E_e(t) \tag{2}$$

R - radius of the dipole hemisphere, in m;

$E_e(t)$ - electrical field intensity from the calibration system, in V/m

For different values of amplitude of the electrical field from the calibration system, the currents of corresponding amplitude will be introduced into the spherical dipole that are noticed by the measuring system and presented on the system scale by numerical indications, which represent the electrical field intensity value (effective or maximum one).

Considering on overhead line, the ground electrical field measuring by the spherical dipole has to take into account the characteristic of this field. In this context, the current value induced into the spherical dipole is calculated starting from general formula that is [1]:

$$i_{d,g.}(x,y,t) = 3\varepsilon_0 \sum_{\Sigma} \frac{d}{dt}\left(\vec{E}(x,y,t) * \vec{e_r}\right) * d\vec{\Sigma} \tag{3}$$

with

$d\vec{\Sigma} = d\Sigma * \vec{e_r}$

$d\Sigma$ - area element on the surface Σ of the dipole hemisphere;

$\vec{e_r}$ - radial unitary vector.

Considering point M situated on the surface of the dipole hemisphere with θ coordinate. Ground electrical field presents, at computing moment T, a deviation angle θ_E in rapport with the direction of the vertical polarization, in this temporal evolution meaning:

$$\theta_E = arctg \frac{|E_x|}{|E_y|} \tag{4}$$

Starting from relation (3) the expression of the induced current will have the following form:

$$i_{d,g.}(t) = 3\omega\pi\varepsilon_0 R^2 E\left(k_1 \cos\theta_E + k_2 \sin\theta_E\right) \tag{5}$$

Depending on the position of vector *E*, this will be situated in quadrants I, II, III, or IV because of time evolution (rotating field), the values of k_1 and k_2 coefficients will be as those presented in table [1]:

Table 1

Values of coefficients k_1 and k_2

Quadrant	Values of coefficients k_1 and k_2	
	k_1	k_2
I	1	1
II	-1	1
III	-1	-1
IV	1	-1

6. The assessments of the measuring errors

The maximum value of the ground electric field intensity $E^{(max)}$ is obtained based on a some complex calculation regarding its determination and on values $E(x,y,t)$ according to the well known formula for different points within a perpendicular plane on the overhead line axis (in the middle of the opening).

If the induced current would be immersed, the maximum value of the current induced into the spherical dipole is determined taking into account the values $i_{d,g}(x,y,t)$ for the concerned calculation points.

By interpolation among the determined values, this maximum current value $i_{d,g}(x,y,t)$, that is $i^{(max)}{}_{d,g}(x,y,t)$, corresponds to the maximum electric field intensity value, $E^{(max)}{}_e$ under the measuring conditions with the spherical dipole into the calibration system, that means:

$$i_{d,e}{}^{(\max)} = i_{d,g}{}^{(\max)} \textit{ corresponds to } E_e^{(\max)} \tag{6}$$

But the current induced, $i_{d,g}{}^{(\max)}$ into the immersed spherical dipole in the ground electrical field corresponds by calculation to its intensity having the maximum value $E^{(max)}$, that is:

$$i_{d,g}{}^{(\max)} \textit{ corresponds to } E^{(\max)} \tag{7}$$

Based on these algorithmic notices, the measuring error of the ground electrical field intensity, ξ, can be established for an overhead electrical line into a perpendicular plane on its axis and in the middle of the opening.

$$\xi(x, y) = \frac{E_e^{(\max)}}{E^{(\max)}(x, y)} - 1, \textit{ in } \% \tag{8}$$

The error variation of measurements for a 400 kV overhead line see [2] or [4] related to the ground electrical field intensity measuring is presented in the figure 3. The measurements have been taken using a dipole by radius R=5 cm.

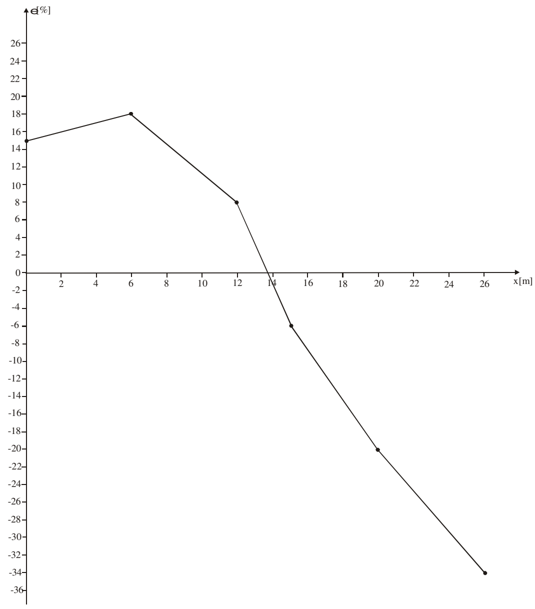

Fig. 3. Measuring error variation ξ (x, y=1.8 m)

7. Conclusions

1. The ground electrical field intensity measured for an overhead line using the spherical dipole method presents some positive and negative errors. The avoiding of these errors can be done only through pre-determination by calculation. In the present, there is no other method with a better accuracy. This is due to the ground electric field characteristics that are different as value and impedance from a line to the other.

2. The error is positive for a distance less than 14 m related to the electrical line axis in our case that means the device indication is bigger than a real indication that device would show. This is given by the distance due to the fact that electrical field has a weak polarization regardless of its direction. If this distance outruns this limit then the polarization became stronger and the direction has a greater and greater horizontal character.

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